

N65-29473

(ACCESSION NUMBER)

(PAGES)

(PAGES)

(NASA CR OR TMX OR AD NUMBER)

THRY

Some Properties of Ferroelectric and Ferromagnetic Compounds RMnO₃

by

P. H. Fang
Goddard Space Flight Center
National Aeronautical and Space Administration
Greenbelt, Maryland

110

Current interest in materials research has lead to the discovery of many new materials with novel properties. In this respect, we noted a system of compounds recently discovered in Grenoble with unusual properties. We will discuss some of these properties in this letter.

These compounds are RMnO₃, where R represents Y, Ho, Er, Tm, Yb, and Lu. ¹ also Sc². In recent years, some ferroelectric materials were reported with ferromagnetic properties, ^{3,4} but to our knowledge, RMnO₃ are the only ferroelectric compounds whose ferromagnetic properties have been definitely established by neutron diffraction analysis. ^{5,2} Ferromagnetic hysteresis loops have been observed in YMnO₃ below the magnetic Curie temperature of 48° K. The coercive field is about 500 Oe. ⁶ Due to the weak ferromagnetic moment, an observation of the magnetic hysteresis loop in the rare earth compounds with large magnetic susceptibilities becomes difficult.

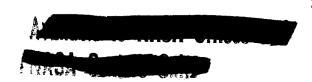


Amed Cabx Cabx

Probably the most interesting experiment on these compounds will be a search for a ferroelectric-ferromagnetic interaction. A magnetic coercive field of 500 Oe is easily accessible. On the other hand, the ferroelectric coercive field of YMnO₃ has been reported ^{1,7,8} as excessively high, in the order of 20 to 100 Kv/cm for 50 cps field at room temperature, with a large variation from specimen to specimen. In Ref. 1, the mated electrodes to the crystal were air-drying Ag-paste and presumably this is also the case in the work of Ref. 7 and 8. Recently we found that with Au evaporated electrodes, the coercive field is only 4.0 ±.5 Kv/cm. This reduced requirement will alleviate greatly experimental difficulties in the contemplated studies of ferroelectric-ferromagnetic interactions.

The ferroelectric switching speed of $YMnO_3$ is reported to be 5 to 10×10^{-8} sec.⁷ This represents highest speed of the ferroelectric switch reported. Due to the above observation of a large reduction of coercive field values by different electrode preparation, it would be interesting to repeat the experiment with Au evaporated electrodes.

The optical properties of the RMnO₃ make them unusual among ferroelectric crystals: aside from the compounds described in Ref. 4, to our knowledge, the RMnO₃ are the only crystals with almost complete total absorption in the region of visible light. However, we observed that appreciable transmission occurs after 0.8μ and extends to the infrared region of 15μ , which is about 3μ farther than that of Ba TiO₃ or Bi₄Ti₃O₁₂. Recent interest in optical non-linear dielectric interactions would make the RMnO₃ an interesting set of material to study.



The variation of dielectric constant of YMnO₃ as a function of the temperature is quite slow in the region from 4.6°K to about 100°K, being about 20%. We have not been able to definitely establish whether there is a dielectric anomaly at the magnetic Curie temperature. To ascertain this anomaly, crystals of large area are desirable, but so far not available.

Single crystals were grown with a $\mathrm{Bi}_2\mathrm{O}_3$ flux, and usually crystals of cm. dimensions can be obtained, but these crystals bind tightly with the flux materials and a separation by a continuous boiling in HNO_3 for many hours results in crystals with an area of a few mm^2 . Another aspect of crystals growth with a $\mathrm{Bi}_2\mathrm{O}_3$ flux is that the thickness is usually confined to 1 to 5×10^{-3} cm. This configuration is not ideal for neutron diffraction analysis or electromagnetic interaction studies. It is most desirable to find other types of fluxes or growth methods in this respect.

Finally, the RMnO₃ have a very high, or probably have no Curie temperature up to the melting point. By a method described elsewhere, we measured the dielectric constant as a function of the temperature. Up to 850°C, no dielectric anomaly was observed. Therefore, the RMnO₃ represent the highest Curie temperature ferroelectric materials.

I would like to thank W. S. Brower of the National Bureau of Standards for growing the crystals used in the present work, and J. E. Wasilik of the National Bureau of standards for some dielectric measurements.

3

REFERENCES

- E.F. Bertaut, F. Forrat and P.H. Fang, Bull. Am. Phys. Soc. <u>8</u>, 61 (1963); Comptes Rendus, Acad. d. Sci. Paris <u>256</u>, 1958 (1963).
- 2. W. C. Koehler, H. L. Yakel, E. O. Wollan and J.W. Cable, Phys. Letters 9, 93 (1964).
- 3. G.A. Smolenskii, V.A. Isupov, A.I. Agranovskaya and N.N. Krainik, Fiz. Tverd. Tela 2, 2982 (1960), [English transl. Soviet Phys. Solid State 2, 2651 (1961)].
- 4. P.H. Fang and R.S. Roth, J. Appl. Phys. Suppl. 31, 2785 (1960). The identification of ferromagnetic properties in these materials is in error. Dr. E. W. Gorter of Philips Research Laboratory at Eindhoven has observed optically a minute amount of small crystals of barium hexaferrite imbedded in these materials. An attempt to prepare specimens entirely free from the barium hexaferrite was not successful.
- 5. E.F. Bertaut and M. Mercier, Phys. Letters 5, 27 (1963).
- 6. R. Pauthenet (Private communications during 1963 Magnetic Conference, Atlantic City).
- 7. P. Guinet, Comptes Rendus, Acad. d. Sci. Paris, 257, 90 (1963).
- 8. V.A. Bokov, G.A. Smolenskii, S.A. Kizhaev and I.E. Myl'nikova, Fiz. Tverd. Tela 5 3607 (1963).
- 9. P.H. Fang and C.R. Robbins, Phys. Rev. 126, 892 (1962).

4